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Report to the Chairman, Subcommittee on Oversight and Investigations, Committee on Energy and Commerce, House of Representatives

January 1992

AIR POLLUTION

Global Pollution From Jet Aircraft Could Increase in the Future

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Air Pollution: Global Pollution From Jet Aircraft Could Increase in the Future

The Honorable John D. Dingell
Chairman, Subcommittee on
Oversight and Investigations
Committee on Energy and Commerce
House of Representatives

Dear Mr. Chairman:

In your February 9, 1990, letter and in our subsequent discussions with your office, you expressed concern about the impact that increased jet engine exhaust emissions could have on the environment. Specifically, you requested that we determine (1) the impact of jet aircraft emissions on both ground-level and global air pollution and (2) the roles played by the various federal agencies in controlling jet aircraft emissions.

Jet aircraft engines emit hydrocarbons, carbon monoxide, carbon dioxide, and nitrogen oxides. At the ground level, defined as 0 to 3,000 feet, pollution from jet emissions includes smog created from hydrocarbons and nitrogen oxides around urban areas. Carbon monoxide can also cause problems in urban areas. At the global level, jet emissions can add to pollution in the upper atmosphere in two ways. First, carbon dioxide emitted by all jets rises into the earth's upper atmosphere to help create a greenhouse effect.[1] Second, nitrogen oxides emitted by supersonic jets cruising between 60,000 and 90,000 feet above the ground can reduce the protective ozone layer.

Results in Brief

Jet aircraft have a minimal impact on pollution problems at ground level. The latest Environmental Protection Agency (EPA) data show that nationwide jet aircraft emissions at the ground level account for less than 0.4 percent of hydrocarbon, nitrogen oxide, and carbon monoxide emissions. Of the five major communities we contacted that are having difficulty meeting national air quality standards, only the metropolitan Los Angeles area, which has severe air quality problems, is implementing ways to reduce jet engine emissions. Chicago, Houston, New York, and Philadelphia officials told us they are not considering actions to reduce pollution from jet engines. According to these officials, controlling emissions from other sources of air pollution, such as motor vehicles traveling to and from

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[1]Although all jets emit carbon dioxide at ground level, carbon dioxide is not a concern until it rises into the upper atmosphere and contributes to global warming.

airports and emissions from oil refineries, would be more cost-effective than attempting to control emissions from jet aircraft.

Jet aircraft contribute little to global pollution in the upper atmosphere, especially compared with contributions from other sources. However, there is concern at EPA and other federal agencies that jet emissions of carbon dioxide and nitrogen oxides could be a concern in the future. The Office of Technology Assessment estimated in a 1991 report[2] that emissions of carbon dioxide in the United States from all aircraft, including jet aircraft, represented about 5 percent of the 1.4 billion tons produced annually from all sources—industry, solid waste disposal, and transportation. Nitrogen oxide emissions from jet aircraft in the stratosphere (60,000 to 90,000 feet) currently have a small impact on upper-level ozone depletion because of the small number of supersonic jet aircraft in operation. But jet aircraft emissions could be a much greater threat to the upper-level ozone layer over the next 14 years if (1) manufacturer estimates of large increases in the number of commercial supersonic aircraft hold true and (2) technology developments cannot reduce emissions to offset the increases.

EPA and the Federal Aviation Administration (FAA) have the principal roles in controlling jet engine emissions. The Clean Air Amendments of 1970 direct EPA to establish aircraft emission standards and direct the Department of Transportation—which delegated the responsibility to FAA—to enforce those standards. EPA established a hydrocarbon standard in 1982 to control hydrocarbon emissions from jet engines. The technology for hydrocarbon control was available and cost-effective for the manufacturers to implement on new engines. And, as EPA had predicted, reductions in hydrocarbon emissions also resulted in reductions in carbon monoxide emissions. EPA did not consider promulgating a carbon dioxide standard because its impact on global warming was unknown at the time EPA was formulating the hydrocarbon standard. The impacts of carbon dioxide emissions continue to be unclear. EPA did not promulgate a standard for nitrogen oxides because technology was unproven and expensive.

FAA enforces the hydrocarbon emissions standard by approving all emissions-testing methodologies and results. FAA also represents the U.S. position on jet aircraft emissions in the international forum that sets ground-level emission standards worldwide. EPA does not participate in this forum, but it helps international and national groups address the global effect of aircraft emissions.

[2] Changing by Degrees: Steps to Reduce Greenhouse Gases (OTA-O-482, Feb. 1991).

The National Aeronautics and Space Administration (NASA) has a role in studying the global impact of jet aircraft emissions. NASA is researching how nitrogen oxides from supersonic jet emissions affect the upper ozone layer, and the agency is developing engine technology to reduce those emissions.

Background

Hydrocarbons, carbon monoxide, nitrogen oxides, and carbon dioxide can all cause health and/or environmental problems. Locally, hydrocarbons and nitrogen oxides can react chemically with sunlight to form ground-level ozone. Ground-level ozone differs from the beneficial ozone in the upper atmosphere that protects the earth from harmful radiation. Ground-level ozone, commonly referred to as "smog," irritates the nose, throat, and lungs, and may lead to permanent lung damage. Carbon monoxide is a colorless, odorless, poisonous gas that can cause impairment of visual perception, manual dexterity, and learning ability.

Carbon dioxide and nitrogen oxides from jet engines can also have global effects in the upper atmosphere. Carbon dioxide is one of the atmospheric gases contributing to the natural "greenhouse effect" of the earth's atmosphere that maintains the planet's average temperature at about 60 degrees Fahrenheit. Fossil fuel combustion, such as burning jet fuel, produces carbon dioxide. Most scientists contend that increases in this gas, as well as in other atmospheric gases, will increase the planet's average temperature over the next 100 years. Scientists disagree on the magnitude of climatic effects from greenhouse gases such as carbon dioxide, and U.S. policymakers have not tried specifically to reduce carbon dioxide emissions. Nitrogen oxides emitted in the upper atmosphere, such as those from supersonic jets, may break down the protective layer of ozone surrounding the earth. This upper ozone layer is vital because it blocks the sun's harmful ultraviolet light that can cause skin cancer.

EPA estimates the ground-level pollution from jet aircraft each year. These estimates are based on annual calculations made by the states on the ground-level pollutions produced by jet engines from hydrocarbon, carbon monoxide, and nitrogen oxide emissions. The states' statistics are based, in part, on data supplied by EPA in a publication entitled Compilation of Air Pollution Emission Factors. This publication is commonly referred to as AP-42. A section of AP-42 contains emission rates for specific aircraft engines and the methodology for states to calculate annual aircraft emissions. The emission rates included in AP-42, however, have not been updated since 1980.

Jet Emissions Are a Small Source of Local Pollution

EPA data show that jet aircraft emissions have a small impact on local air pollution. EPA's latest data, for 1989, show that jet aircraft contributed 0.3 percent of the total hydrocarbons, 0.3 percent of the total carbon monoxide, and 0.4 percent of the total nitrogen oxides in ground-level air. In sum, jet engine emissions accounted for about 317,000 tons, or about 0.3 percent, of the 109.2 million tons of these three pollutants produced nationwide.[3] (See app. I for more details on emissions contributions of jet engines and other sources nationwide.)

In addition, EPA's 1989 data most likely overstate how much jet aircraft contribute to total emissions. The agency's data on jet emissions have not been updated since 1980 because of the small impact that these emissions have had on air quality, as compared with other sources. As a result, the data do not reflect changes in jet engine technology that have reduced emissions from engines built since 1982, when EPA published the new hydrocarbon standard. However, in July 1991 EPA provided the states with a draft copy of updated emissions data that reflects lower emissions from jet engines. An agency official expects the final data will be basically the same as the draft. According to an EPA official, local communities are using the updated draft data to determine the current estimates of jet aircraft emissions. The estimates from the states will not be available until February or March 1992, according to another EPA official.

Our analysis of emissions test data provided by the International Civil Aviation Organization (ICAO), for engines built before EPA published the standard in 1982 and after publication of the standard, showed that jet engines are getting cleaner. ICAO collects emission data from jet engine manufacturers worldwide in making decisions on emission standards. Our analysis showed that jet engines built after 1982 emitted an average of 85 percent fewer hydrocarbons after the standard was published. The technology that lowered hydrocarbon emissions has also lowered carbon monoxide emissions by 70 percent. But the hotter engine temperatures used to reduce hydrocarbons and carbon monoxide led to a 12-percent increase in nitrogen oxide emissions. Overall, the total amount of all three emissions decreased 58 percent. (Our analysis of emissions test data is described in more detail in app. II.)

[3]In 1989 EPA data showed that general aviation aircraft produced about 774,000 tons, or 0.7 percent, and military aircraft produced about 314,000 tons, or 0.3 percent, of the nationwide totals of the three pollutants. EPA data do not break out emissions from jet engines versus gasoline engines for general aviation and military aircraft.

About 2,400, or 50 percent, of the 4,800 U.S. jet aircraft operating in July 1991[4] were added to the commercial fleet after EPA published its standard in 1982. We estimate that by the year 2017, the entire fleet will have the cleaner engines that meet the emissions standard. While estimates of the useful economic life of jet aircraft may vary, our calculation is based on FAA's estimate that the useful economic life could be as long as 35 years.

Despite the installation of cleaner engines on 50 percent of the jet aircraft fleet, an increase in jet aircraft departures has to some degree offset the overall reductions achieved by the hydrocarbon standard. Between 1982 and 1988, aircraft departures rose from about 5.1 million to about 7.0 million, an increase of 37 percent.

Jet aircraft emissions also have a small impact in urban areas that cannot meet national air quality standards. In the metropolitan Los Angeles area—the region with the most severe air quality problems in the nation—the latest available EPA data for local areas show that in 1985, jet aircraft contributed about 18,000 tons, or about 0.5 percent, of the 3.6 million total tons of hydrocarbon, carbon monoxide, and nitrogen oxide emissions. Organic solvent evaporation (27,000 tons) and trash and yard waste burning in residential areas (24,000 tons) contributed more pollutants to the Los Angeles area in 1985 than jet emissions.

Because of the severity of the pollution in the Los Angeles area, this community is attempting to reduce emissions from many small sources, including jet aircraft. Los Angeles metropolitan officials modified airport gates to provide power to run aircraft electrical systems so that engines do not have to idle in the airport terminal area. Officials also added remote gates and runways to reduce the amount of time aircraft spend idling their engines and taxiing.

Officials from four other communities with air pollution problems —Chicago, Houston, New York, and Philadelphia—told us that jet aircraft emissions are a small source of pollution. These officials have found it more cost- effective to focus attention on large sources of pollution, such as automobiles. (See app. III for more details on the five communities' perspectives on jet engine emissions.)

[4]Jet aircraft fleet numbers supplied by Aviation Data Service, Inc., Wichita, Kan.

Global Pollution From Jet Aircraft Could Be a Future Concern

Jets currently contribute a relatively small amount of carbon dioxide emissions to global pollution. An Office of Technology Assessment analysis showed that in 1987 all sources combined in the United States produced 1.4 billion tons of carbon dioxide emissions. The analysis showed that all aircraft, including jet aircraft, contributed about 65 million tons of carbon dioxide emissions, or about 5 percent of the total, in that year.

An EPA official told us that scientific uncertainty about both the impact of global warming and the percentage of greenhouse gases attributable to jet aircraft emissions makes it premature for EPA to identify any action that it needs to take. Current scientific study results are preliminary and unproven, according to EPA officials. While jet aircraft emissions are currently not a proven problem, the agency plans to continue monitoring concerns about greenhouse gases attributable to aircraft emissions in case problems develop that require action.

Emissions of nitrogen oxides from supersonic jets currently have a small impact on upper-level ozone depletion. Although nitrogen oxide emissions in the stratosphere erode the ozone layer, NASA scientists agree that the current fleet of 13 commercial supersonic jets flying in the stratosphere is not a threat to erosion of the upper ozone layer.[5] The effect of supersonic aircraft on the upper ozone layer will be a concern, however, if market projections hold true. Industry and government market analyses, using various considerations like fare structures and fuel prices, project a fleet of 300 to 1,200 commercial supersonic jets to be in service in the next 10 to 34 years if anticipated technology improvements are made. NASA, with input from aircraft industry officials, will assume a fleet size of 500 supersonic jets by the year 2015 for its initial projections of emissions impacts on upper ozone depletion. NASA plans to vary the fleet size projections in later analyses. A scientific adviser to NASA indicated that technology improvements are necessary because without these improvements, an estimated 500 to 600 supersonic aircraft could reduce the protective ozone layer by as much as 15 percent. NASA's study of this issue is discussed in the next section of this letter.

For each 1-percent reduction in upper-level ozone concentration, scientists predict harmful ultraviolet radiation will increase by roughly 2 percent. In turn, EPA estimates that with a 2-percent increase in harmful ultraviolet radiation, the incidence of non-melanoma skin cancer in the United States

[5]The 13 supersonic jets do not include a few military aircraft operated by the Department of Defense (DOD), according to a NASA official. The few military aircraft operating in the stratosphere also do not pose a threat to upper-level ozone depletion, according to NASA.

would increase by about 2 to 6 percent over the current rate of roughly 400,000 new cases per year. EPA also estimates the incidence of malignant melanoma in the United States would increase by 1 to 2 percent over the current rate of about 26,000 new cases, and 6,000 fatalities, per year. Any ozone reduction could be harmful because recent data suggest that the ozone layer has depleted far more than previous studies have shown. For example, NASA estimates that the winter ozone levels at 40 degrees north have decreased by about 4.7 percent from 1969 to 1986, compared with a previous estimate of about a 1.5- percent decrease for the same period. (See app. IV for an illustration depicting the depletion of the ozone layer.)

Because of EPA's concerns about the potential impact of jet aircraft emissions at the global level, the agency has decided to add a staff position primarily to monitor NASA's research on the effect of jet emissions on upper-level ozone depletion problems. The staff person will also be monitoring studies on the impact of jet emissions on greenhouse gas problems. As of December 1991, EPA had a contractor fulfilling these responsibilities and expected to hire a full-time staff person in the future to assume this role.

Federal Roles in Controlling Jet Aircraft Emissions

The agencies primarily responsible for controlling jet aircraft emissions are EPA and FAA. The Clean Air Amendments of 1970 directed EPA to study emissions of air pollutants from aircraft. The 1970 amendments also required EPA to issue proposed standards applicable to emissions from any aircraft engine that caused or contributed to air pollution and thereby endangered the public health or welfare. EPA first proposed aircraft standards in 1973. They covered a variety of engines and were applicable to emissions of hydrocarbons, carbon monoxide, and nitrogen oxides.

EPA, in a joint study with FAA, subsequently concluded in 1980 that aircraft had a relatively small impact on urban emission problems. Earlier, EPA had said that instituting comprehensive controls would not be a good use of manufacturer and government resources. Instead, EPA set only a hydrocarbon standard in 1982 because it was cost- effective to control. The hydrocarbon standard applied only to jet aircraft used for commercial purposes. EPA exempted general aviation aircraft from meeting the hydrocarbon standard because it did not consider control of those aircraft to be cost-effective. EPA has not changed the hydrocarbon standard or added any new standards to control other jet aircraft emissions since 1982. As mentioned previously, EPA also helps local communities and states assess the impact of jet aircraft on local air quality by providing them with a listing of

specific types of jet aircraft and their operating characteristics and emissions.

The Clean Air Amendments of 1970 give the Department of Transportation, which delegated the duties to FAA, the responsibility for establishing regulations to ensure compliance with the emissions standards. FAA procedures include reviewing compliance with EPA emissions standards; this review is part of the agency's other responsibilities concerning air transportation safety and engine certification. For instance, in addition to certifying aircraft for emissions compliance, FAA assesses all the safety aspects of aircraft—such as the plane's structure, the performance of new aircraft, and the operation and maintenance of the air traffic control network.

According to FAA officials, FAA generally does not attend the actual emissions testing of an engine. Rather, the agency relies on manufacturers to do the actual testing of aircraft and aircraft components because FAA does not have the necessary equipment and staff to conduct the tests. Officials told us that they train and certify manufacturers' representatives, who represent FAA at the actual testing and then document and submit test results to FAA for approval. Emissions testing procedures include approving the test design, inspecting the testing facility and equipment to make sure they meet specifications, and reviewing the final test results. According to an FAA official, engine emissions testing typically takes about a month to plan and set up, and another week to conduct. Since the EPA hydrocarbon standard became effective in 1984, 38 new types of jet engines have been introduced and tested by engine manufacturers to determine if they comply with the hydrocarbon standard. FAA collects data from engine manufacturers on carbon monoxide and nitrogen oxides at the same time that it collects hydrocarbon data to determine if these emissions meet the ICAO standards. ICAO member nations accept FAA's certification that U.S. aircraft destined for international flight meet ICAO emissions standards.

FAA also represents the United States on a working group of ICAO's Committee on Aviation Environmental Protection. The United Nations established ICAO in 1947 to address issues relating to international civil aviation such as safety and emissions. ICAO and its 162 member nations, including the United States, determined that jet aircraft emissions standards were needed for, among others, hydrocarbons, carbon monoxide, and nitrogen oxides, to improve ground- level air quality worldwide. At the December 1991 ICAO meeting, part of the agenda included a discussion of emissions standards. According to an FAA official, the working group of the

Committee on Aviation Environmental Protection recommended making the nitrogen oxide standard more stringent by reducing the standard 20 percent. This recommendation is not expected to become effective until 1993, and only after adoption by the full ICAO. Since ICAO cannot levy penalties or otherwise enforce compliance with emissions standards, it must rely on member nations for implementation.

Member countries have expressed an interest in having EPA attend the working group meetings to represent U.S. environmental interests. Although EPA was active in attending ICAO meetings around the mid 1980s, it has attended only one meeting since. According to an FAA official, FAA has extended invitations over the past 3 or 4 years for EPA to attend the working group meetings. EPA officials told us they do not plan to attend future meetings because aircraft emissions are a low priority among their many responsibilities under the Clean Air Act Amendments of 1990. Currently EPA is devoting its staff to higher- priority air issues, such as mandated automobile standards, inspection and maintenance requirements, and reformulated gasoline regulations.

NASA also has a role in addressing emissions from jet aircraft. The Congress gave NASA a $284 million budget over 6 years, beginning in fiscal year 1990, to develop the technology to help the United States keep its lead in the commercial supersonic aircraft market.[6] The industry predicts that supersonic jet aircraft could play a more important role in the growing commercial aircraft market and that the United States is in danger of losing its lead to other countries, such as France and Japan. NASA's objective is to develop new supersonic jet engine technology that will meet strict limits on airport noise and sonic boom levels; be competitive with a new generation of efficient, long-haul subsonic aircraft; and add no significant damage to the atmospheric ozone layer.

A NASA program manager explained that $100 million of the $284 million will be used for atmospheric science and research that will focus on reducing current nitrogen oxide emissions to prevent further harm to the ozone layer. NASA's objectives include developing technology that would permit a 90-percent reduction in nitrogen oxide emissions from proposed supersonic jets. The NASA program manager said that at this emissions level, jets would reduce the upper-ozone layer by less than 1 percent even if projections of a fleet of 500 to 600 supersonic jets over the next 25 years come true. Early modeling results were encouraging and some predictions

[6]Committee Print, Senate Committee on Commerce, Science, and Transportation, Commercial High-Speed Aircraft Opportunities and Issues, Mar. 1989.

of atmospheric effects should be available by February 1992, according to a NASA program manager. If the test results are positive, the next step is to have engine manufacturers evaluate the technology by the end of 1995. But even this level of "success" could increase skin cancer deaths, on the basis of EPA's estimates of 6,000 deaths per year for a 1-percent reduction of upper-level ozone.

DOD has a lesser role in monitoring jet aircraft emissions. DOD's aircraft are exempt from FAA's civil aeronautics regulations, including the requirement to obtain an airworthiness certificate. Because of this exemption, DOD does not have to meet the EPA hydrocarbon standard, but the services within DOD are responsible for reporting their emissions to the EPA regional office in whose jurisdiction they are located.[7] The National Environmental Policy Act of 1969 requires federal agencies, including the military, to analyze the potential environmental impacts of proposed actions, such as changes in base operations, that affect environmental quality. EPA and local communities use this information when developing their air quality improvement strategies.

Military jet aircraft generally meet emissions standards, according to officials, except when combat performance and/or safety might be compromised. According to Air Force officials, the Air Force sets goals for emissions reductions for its jet aircraft comparable to the requirements of the Clean Air Act. An official told us that Air Force policy is to meet exhaust emissions standards whenever possible. Navy officials also told us that they support engine emission reductions but do not require jet engine manufacturers to meet emission standards if compliance would affect combat performance. According to Army officials, the Army is aware of emissions requirements but has only three jet aircraft, which are used mainly for transporting senior officials.

Conclusions

Jet aircraft continue to have a minimal impact on ground- level air pollution. For the most part, innovations in aircraft technology have made engines cleaner since EPA set the hydrocarbon standard in 1982. However, innovations in aircraft technology have also raised new concerns on a global scale. Supersonic aircraft have been developed that can fly in the upper ozone layer that protects all living things from the harmful effects of

[7]EPA's aircraft emissions regulations define aircraft as an airplane for which an FAA airworthiness certificate is issued. Since DOD aircraft are not required to obtain an airworthiness certificate, they are not within the definition of aircraft under EPA's regulations; therefore they are exempt from EPA's emissions standards.

ultraviolet light. Emissions from these supersonic aircraft can reduce the layer of this ozone, making people more susceptible to skin cancer.

The effect of commercial supersonic aircraft on the upper ozone layer is not a major problem at this time because there are only about a dozen of such aircraft in use. However, several hundred may be in service within the next 25 years. If these predictions come true, and no improvements are made in emissions technology, the impact on the upper ozone layer and human health could be substantial. NASA and jet engine manufacturers stated that large numbers of supersonic jet aircraft would not be built unless nitrogen oxide emissions can be reduced to an environmentally acceptable level. However, there is nothing to prevent manufacturers from doing so because there is no U.S. nitrogen oxide standard. In addition, preliminary but unproven research suggests that jet aircraft emissions may be adding to greenhouse gas problems. While research results are premature for determining what action is needed, EPA is monitoring studies to be aware of growing concerns. Because of these global concerns about jet aircraft emissions, it is important that EPA continue its current efforts to closely monitor studies and research on global pollution from jet aircraft so that it will be in a position to develop a federal response to minimize any environmental consequences that develop.

Scope and Methodology

We conducted our review from September 1990 to November 1991 in accordance with generally accepted government auditing standards. We focused our review on jet aircraft used by airlines for commercial purposes, such as transporting travelers and cargo. We excluded general aviation and military aircraft because data were not available to identify emissions from jets versus emissions from other types of aircraft in these categories.

To determine the impact of jet emissions on both local and global pollution, we gathered information from EPA on emissions nationwide as well as in some urban areas. We also contacted several state and local agencies to identify the impact of jet emissions on pollution around towns and cities. Jet engine manufacturers and aircraft industry officials gave us information on specific jet engine emissions. We reviewed available materials and interviewed environmental groups and NASA officials to identify the possible impact of jet emissions on global warming and upper-level ozone depletion. To determine the roles played by various federal agencies in controlling jet emissions, we visited EPA and FAA, as the agencies with primary roles in controlling jet emissions. We also interviewed agencies with other roles,

like NASA and DOD. We discussed the facts contained in this report with EPA, FAA, NASA, DOT, and DOD officials and made changes as appropriate; however, as requested we did not obtain written agency comments. A detailed description of our objectives, scope, and methodology is contained in appendix V.

As agreed with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of this letter. At that time we will send copies to the Administrator of EPA, the Secretary of Transportation, the Administrator of FAA, the Secretary of Defense, and the Administrator of NASA. Copies will be made available to others on request. If you have questions regarding the information contained in this report, please contact me at (202) 275-6111. Major contributors to this report are listed in appendix VI.

Sincerely yours,

Richard L. Hembra
Director, Environmental
Protection Issues

Contents

Abbreviations

DOD	Department of Defense
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
ICAO	International Civil Aviation Organization
NASA	National Aeronautics and Space Administration

Contribution of Jet Engine Emissions on a National Scale

EPA data show that estimated commercial jet engine emissions of hydrocarbons, carbon monoxide, and nitrogen oxides contributed about 317,000 tons, or 0.3 percent, of the estimated 109 million tons of these three emissions produced from all sources in 1989, the most recent year for which EPA has data. As shown in table I.1, other sources of emissions such as highway vehicles, natural gas fuel, and solid waste disposal have a much larger impact on air pollution than do jet aircraft emissions. For example, highway vehicles accounted for about 48 million tons of these pollutants, or 44 percent of the total, in 1989.

EPA officials explained that the most recent national air pollutant emissions, published in March 1991, contain estimates based on 1989 data, the latest available. For aircraft landing and take-off information, EPA depends on other agencies—like FAA— publishing the most recent data. Also, state and local officials have until the end of April to finish gathering information on air monitoring systems for the previous year; EPA usually receives this information a few months later, around July. EPA's analysis of the data takes until February of the following year. For example, 1989 data from state and local agencies came in to EPA about July 1990. EPA completed its analysis by February 1991 and published the estimated emissions in March 1991. EPA officials stated that they are striving to issue preliminary 1990 data in the fall of 1991, but the complete emissions estimates will still not be published until February or March 1992.

Table I.1: Estimated 1989 National Emissions (Hydrocarbons, Carbon Monoxide, Nitrogen Oxides)

Source and category	Tons	Percent of total, all sources
Highway vehicles	48,121,700	44.0
Vessels	2,623,500	2.4
Farm machinery	2,612,500	2.4
Construction machinery	968,000	.9
Jets	**316,935**	**.3**
Other transportation	5,084,065	4.6
Total transportation	**59,726,700**	**54.6**
Wood	8,529,400	7.8
Coal	8,246,700	7.5
Natural gas	4,140,400	3.9
Fuel oil	739,200	.7
Other fuel	105,600	.1
Total stationary fuel combustion	**21,761,300**	**20.0**
Petroleum refining, storage, and transfer	3,054,100	2.8
Surface coating	2,002,000	1.8
Carbon black	1,154,400	1.1
Pulp mills	1,031,800	.9
Iron and steel	1,014,200	.9
Crude oil production, storage, and transfer	601,700	.6
Plastic	411,400	.4
Printing & publishing	258,500	.2
Dry cleaning	233,200	.2
Iron foundries	161,700	.2
Other industrial processes	2,935,900	2.7
Total industrial processes	**14,632,700**	**13.4**
Forest fires	7,920,000	7.3
Misc. organic solvents	1,760,000	1.6
Other burning	770,000	.7
Total miscellaneous	**10,450,000**	**9.6**
Solid waste disposal	2,640,000	2.4
Total all sources	**109,210,700**	**100.0**

Small sources such as printing and publishing, and dry cleaning, each produce about the same amount of emissions as jet aircraft. For example, printing and publishing processes in 1989 contributed 258,500 tons, or 0.2 percent, of the national total of emissions. Other small sources like crude oil production and plastic manufacturing contribute significantly larger amounts of emissions than jet engines. Crude oil production in 1989 produced 601,700 tons, or 0.6 percent, of these emissions—nearly two times more than jet engines.

Transportation sources account for about 60 million tons, or almost 55 percent, of the national total of these emissions. Highway vehicles account for about 44 percent of the total, while off- highway transportation sources account for about 11 percent of the total. Jet engine emissions, at 0.3 percent of the total, account for the smallest portion of emissions from off-highway transportation sources. Vessels and farm machinery each contribute over 2.6 million tons, or 2.4 percent each, of the total – and at least three times the emissions as jet engines produce.

As shown in table I.2, even when the total emissions from two sources are about the same, the individual pollutants making up the total can vary greatly. For example, dry cleaning and jet aircraft produce about the same total amount of emissions. However, 100 percent of the emissions from dry cleaning consist of hydrocarbons, while only 19 percent of jet aircraft emissions is comprised of hydrocarbons. The majority of aircraft emissions—about 56 percent—is made up of carbon monoxide, with the remaining 25 percent comprised of nitrogen oxides.

Table I.2: Estimated 1989 National Emissions From Individual Pollutants

Tons in millions

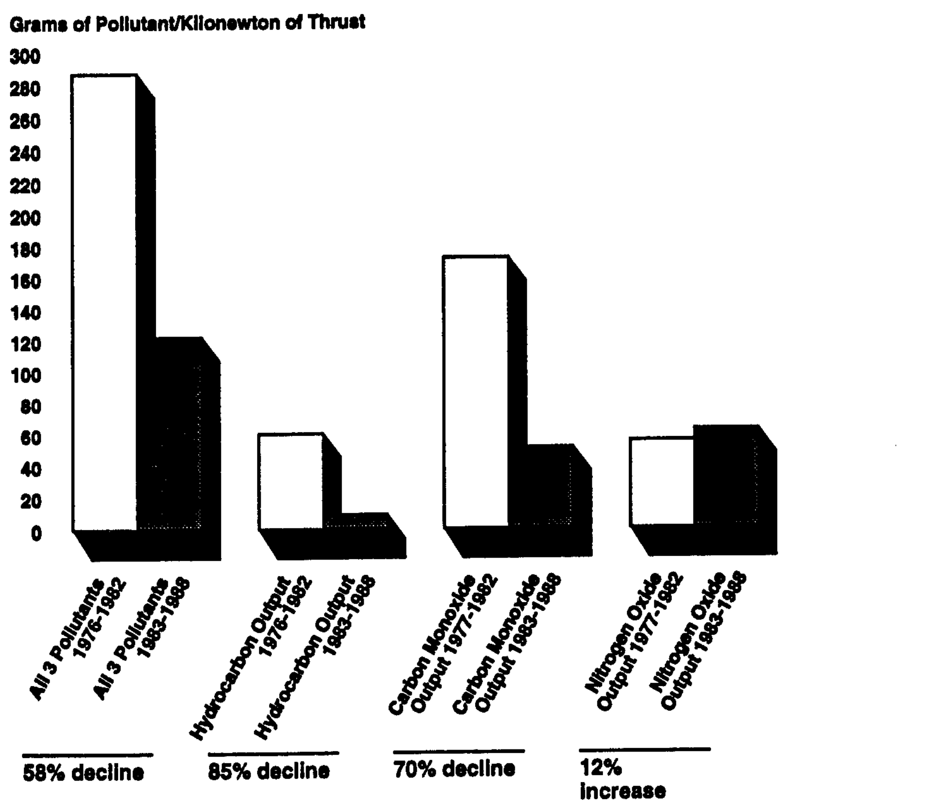
Source and category	Hydrocarbons	Carbon monoxide	Nitrogen oxides
Highway vehicles	5.63	35.96	6.54
Vessels	.54	1.83	.25
Farm machinery	.20	1.80	.61
Construction machinery	.06	.62	.30
Jets	**.06**	**.18**	**.08**
Other transportation	.56	3.59	.94
Total transportation	**7.05**	**43.97**	**8.71**
Wood	.86	7.45	.22
Coal	.06	.46	7.73
Natural gas	.01	.09	.63
Fuel oil	.08	.53	3.53
Other fuel	.01	.02	.08
Total stationary fuel combustion	**1.02**	**8.56**	**12.19**
Petroleum refining, storage, and transfer	2.46	.36	.24
Surface coating	2.00	–	–
Organic chemicals	1.09	.62	.07
Carbon black	–	1.16	–
Pulp mills	–	1.00	.03
Iron and steel	.19	.76	.06
Crude oil production, storage, and transfer	.60	–	–
Plastic	.41	–	–
Printing & publishing	.26	–	–
Dry cleaning	.23	–	–
Iron foundries	–	.16	–
Other industrial processes	1.66	1.02	.25
Total industrial processes	**8.91**	**5.08**	**.65**
Forest fires	.88	6.82	.22
Misc. organic solvents	1.76	–	–
Other burning	.11	.66	–
Total miscellaneous	**2.75**	**7.48**	**.22**
Solid waste disposal	.66	1.87	.11
Total all sources	**20.39**	**66.95**	**21.88**

Jet Engine Emissions Since Publication of Hydrocarbon Standard

To determine if changes had occurred in jet engine emissions since EPA issued the hydrocarbon standard in 1982, we obtained the latest available emissions test results that manufacturers send to the International Civil Aviation Organization (ICAO). Of the emissions test results we obtained for 81 engines tested between 1976 and 1988, we had complete data for only 77 engines. We analyzed the emissions test results from 19 engines tested from 1976 to 1982, and compared results with the emissions of the 58 engines tested from 1983 to 1988. As shown in figure II.1, average hydrocarbon emissions decreased 85 percent, average carbon monoxide emissions decreased 70 percent, and average nitrogen oxide emissions increased 12 percent. Total average emissions decreased 58 percent.

Although EPA set only a hydrocarbon standard, the technology that lowered hydrocarbon emissions also lowered carbon monoxide emissions. In turn, the hotter engine temperatures that reduced hydrocarbon emissions caused nitrogen oxide emissions to rise somewhat.

Figure II.1: Jet Engine Emissions Before and After 1982



Perspectives of Five Communities on Jet Emissions

In the five communities we contacted—Los Angeles, Chicago, Houston, New York, and Philadelphia—the contribution of jet emissions in 1985 to total hydrocarbon, carbon monoxide, and nitrogen oxide emissions ranged from a low of 0.4 percent in Houston to 0.9 percent in Chicago and New York. Data for 1985 included jet aircraft contributions in individual communities; after 1985 EPA discontinued these listings and the data show aircraft contributions, including jets, on a national scale only. The following sections provide additional perspectives on the consideration given to jet engine emissions in each community.

Los Angeles, Cal.

The metropolitan Los Angeles area has the worst air quality problems in the nation. In 1989 (the latest data available) EPA's pollutant standards index showed that the Los Angeles metropolitan area exceeded national air quality standards on 213 days. The other four communities exceeded the national air quality standards for 39 days or less.

Table III.1: Failure to Meet Air Quality Standards in 1989

Urban Area	Number of days standards were executed
Los Angeles	213
Philadelphia	19
Houston	37
New York	39
Chicago	2

Because of such severe smog problems, metropolitan Los Angeles has taken measures to control not only large sources of pollution such as motor vehicles and industrial waste burning but also small sources such as service stations and jet aircraft. To control jet aircraft emissions, Los Angeles modified airport gates to provide power to run aircraft electrical systems so that engines do not have to idle in the airport terminal area. The city also modified airport procedures to reduce the time that aircraft spend idling and taxiing at the airport. A Los Angeles official told us that some of the jet emission reduction measures were not cost- effective but had to be implemented because the air quality problems were so severe.

Chicago, Ill.

Officials from the Illinois Environmental Protection Agency told us that, unlike Los Angeles officials, Chicago does not try to control small pollution sources such as jet aircraft because they do not have the same extreme air quality problems. Chicago focuses on large pollution sources instead. Chicago has control measures for sources such as motor vehicles, surface-coating operations like painting, and some petroleum refining. By addressing larger sources, a state official said Chicago had been successful in lowering the number of days the area exceeded the ozone standard from 15 in 1988 to 2 in 1989. However, the new Clean Air Act Amendments of 1990 may require that Chicago institute controls in the future for some smaller sources such as dry cleaning and autobody refinishing, according to one state official.

Houston, Tex.

A Houston airport official told us that no steps are being taken to control pollution at the airport from stationary sources, motor vehicles, or jet aircraft. Pollution reduction measures for the Houston metropolitan area focus on larger pollution sources, including several controls for motor vehicles such as enhanced inspection and maintenance. Pollution control measures are also aimed at the petrochemical industry, which is extensive in Houston. Officials were not aware of any particular pollution controls aimed at smaller sources such as jet aircraft.

Philadelphia, Pa.

A Pennsylvania Department of Environmental Resources official told us that in Philadelphia they focus on reducing emissions from larger sources such as motor vehicles, gas pump vapor, and tankers and barges loading on the Delaware River. Philadelphia has not considered targeting smaller sources such as jet aircraft. In the future, Philadelphia may have to include controls for some smaller sources such as bakeries, but a state official said Philadelphia is waiting for EPA guidance on requirements of the Clean Air Act Amendments of 1990. However, jet aircraft is too small a source for Philadelphia to consider for controls.

New York, N.Y.

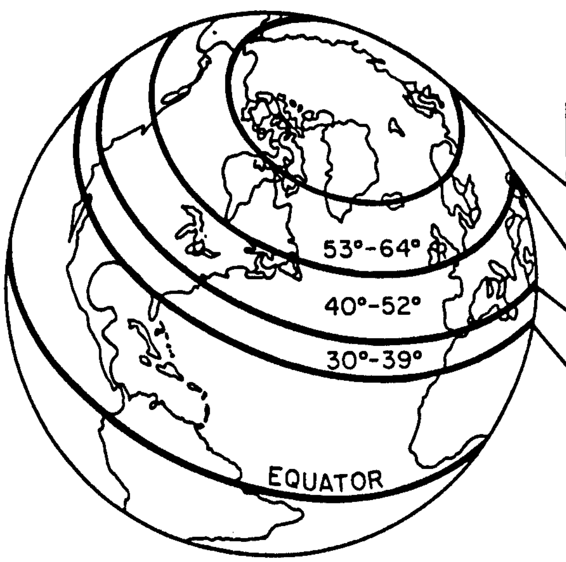
A New York State Environmental Conservation Department official told us that because of limited resources, New York City focuses emission reduction efforts on pollution sources that are the most cost-effective to control. Their control efforts include the Clean Air Act requirements for automobiles as well as both large and small stationary sources. Although New York regulates some small sources, it currently does not have regulations that

affect jet or general aviation aircraft, nor is it considering regulating aircraft emissions.

Depletion of the Ozone Layer

According to an Office of Technology Assessment report, NASA estimated that the average percentage of changes in the upper ozone layer for the mid-latitudes in the Northern Hemisphere has decreased between 1.7 percent and 3.0 percent from 1969 to 1986, as shown in figure IV.1. As mentioned earlier, for each 1 percent reduction in upper-level ozone concentrations, ultraviolet radiation is predicted to increase by roughly 2 percent.

Figure IV.1: Estimated Changes in Total Ozone in Northern Hemisphere, 1969-86[1]



Average % Change 1969 -1986	Winter Change	Summer Change
-2.3%	-6.2%	+0.4%
-3.0	-4.7	-2.1
-1.7	-2.3	-1.9

The Office of Technology Assessment reported that in October 1987, the amount of ozone over the Antarctic fell to the lowest levels ever observed. Averaged over 10-degree latitude bands extending from 60 to 80 degrees south, the amount of ozone directly overhead at any given site had dropped between 24 to 50 percent since October 1979. The Antarctic ozone hole appeared in both 1989 and 1990, the first time such depletion was observed in 2 consecutive years. The 1990 hole was nearly as severe as the record depletion levels found in 1987, and it persisted longer.

[1]U.S. Congress, Office of Technology Assessment, Changing by Degrees, Steps to Reduce Greenhouse Gases, OTA-O-482 (Washington, D.C.: U.S. Government Printing Office, Feb. 1991).

Objectives, Scope, and Methodology

Our objectives were to determine the (1) impact of jet aircraft emissions on both ground-level and global pollution and (2) roles played by various federal agencies in controlling jet aircraft emissions.

To determine the air pollution impact of jet aircraft emissions at the ground level, we obtained nationwide data from EPA's Office of Air Quality Planning and Standards on all sources of emissions of hydrocarbons, carbon monoxide, and nitrogen oxides. EPA does not collect data on carbon dioxide emissions because it does not consider carbon dioxide toxic. We then compared jet engine emissions data on hydrocarbons, carbon monoxide, and nitrogen oxides to all other emission sources contributing to air pollution to determine the percentage attributable to jet aircraft.

EPA officials told us that the jet aircraft emissions data we obtained were about 10 years old and therefore did not reflect improvements made by engine manufacturers to meet the hydrocarbon standard. To determine changes made in emission reductions since the hydrocarbon standard, we obtained emissions information from ICAO which collects emissions data from jet engine manufacturers worldwide. The ICAO data bank contained complete emissions data for 77 jet engines. An ICAO official was unsure whether this represented data on all jet engines currently in operation. To determine whether we had representative emissions data for the jet fleet, we compared the 77 with the number of different types of engines represented in the updated AP-42 data. An EPA official told us that the new updated emissions data in AP-42 would contain emissions data for about 80 jet engines. As a result, the ICAO emissions data for the 77 jet engines appear to represent the majority of the jet engine population. On the basis of this comparison of pre- and post-standard engines, we calculated the average change for hydrocarbon, carbon monoxide, and nitrogen oxide emissions.

To determine whether jet emissions have an impact in urban areas with air pollution problems, we contacted five metropolitan areas —Chicago, Ill.; Houston, Tex.; Los Angeles, Cal.; New York, N.Y.; and Philadelphia, Pa. We chose these areas because they are (1) geographically dispersed across the U.S., (2) are among the communities having the most difficulty meeting air quality standards, and (3) have large airports with high jet aircraft activity. We obtained pollution data on the five metropolitan areas from the EPA Office of Air Quality Planning and Standards, and discussed pollution data with five EPA regional offices (Region II for New York; Region III for Philadelphia; Region V for Chicago; Region VI for Houston; and Region IX for Los Angeles). We also discussed pollution data with the state

environmental office in each community (New York State Environmental Conservation Department, Pennsylvania Department of Environmental Resources, Illinois Environmental Protection Agency, Texas Air Control Board, and California Environmental Protection Agency). From these data we determined specific air pollution problems facing some urban communities and the impact of jet aircraft in those areas. We asked officials from each of these areas if emissions from jet aircraft are a pollution problem and, if so, whether any control measures are being taken.

Also, we contacted several major airlines (American Airlines, Delta Airlines, Northwest Airlines, Trans World Airlines, United Airlines) and aircraft industry organizations (Aerospace Industries Association of America, Air Transport Association, Airport Operators Council International, General Aviation Manufacturers Association) to determine the impact of jet emissions, trends in technology, or fuel economy measures to control emissions.

To determine the impact of jet emissions on air pollution at the global level, we interviewed officials at EPA, the Office of Technology Assessment, and the National Academy of Sciences that were responsible for studies on global warming, and also interviewed NASA officials researching upper-level ozone depletion. We contacted environmental groups (the Environmental Defense Fund, the National Clean Air Coalition, the Sierra Club) and other federal agencies (the Department of Energy, the National Oceanic and Atmospheric Administration) to determine if they had conducted any studies involving jet aircraft emissions that might highlight the impact of jet aircraft on pollution in local areas and globally.

To determine the federal roles in controlling jet emissions, we interviewed officials from EPA and FAA, the major agencies responsible for controlling jet aircraft emissions; and officials from DOD and NASA, which have other roles in assessing jet emission impacts. At EPA headquarters, we visited the agency's Office of Mobile Sources, which is responsible for setting aircraft standards. We also visited EPA's Office of Atmospheric and Indoor Air Programs, which is responsible for monitoring effects of jet aircraft emissions at the global level. We interviewed officials and obtained data on aircraft emissions from EPA's Office of Air Quality Planning and Standards.

At FAA headquarters, we visited the agency's Office of Energy and Environment, whose role is enforcing EPA jet emission standards. This FAA office also represents the United States on the ICAO committee that sets international emissions standards. We visited the FAA New England Region

Engine and Propeller Certification Directorate, which monitors jet engine testing and certifies compliance with EPA standards.

We contacted NASA officials at headquarters in Washington, D.C.; Goddard Flight Research Center in Washington, D.C.; Lewis Research Center in Cleveland, Ohio; and Langley Research Center in Hampton, Va. that are involved in NASA research on supersonic jet aircraft emissions and their impact on upper-level ozone depletion. We obtained information from these officials on the scope, objectives, and status of a $284 million research project on the effects of supersonic jet aircraft, including upper-level ozone depletion. DOD officials from the Air Force, Army, and Navy provided us with data on their policies and roles in monitoring military aircraft emissions at military air bases.

We interviewed officials from ICAO and reviewed documentation on international standards and recommended practices in testing jet emissions. We interviewed the FAA official who is a member of the ICAO Committee on Aviation Environmental Protection to determine the role and relationship of ICAO international standards with U.S. standards for jet emissions control.

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